A Shimming Technique for Improvement of the Spectral Performance of APS Undulator A

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1. Introduction

The performance of insertion devices would achieve almost the ultimate level if a proper set of techniques could be developed to correct the magnetic field imperfections. It has been shown experimentally [1-3] that the measured radiation characteristics of a magnetically fine-tuned insertion device are very close to those calculated for an ideal device. There are different techniques for correction of magnetic field errors. One used most often is a shimming technique capable of correcting both integrated and local field errors [1, 2, 4]. In this note, some specific results of a shimming technique applied to APS insertion devices will be presented.

The insertion device (ID) most widely in use at the APS storage ring is an Undulator A [5]. It has 72 periods of hybrid "wedge-pole" magnetic structure with a period length of 33 mm. There is a 0.25-mm recess between the tops of the poles and the magnets.

One of the magnetic tuning procedures developed and implemented at the APS targets the minimum value of phase errors for Undulator A. It has been shown recently that the rms phase errors are very well correlated with the ID performance and therefore could be accepted as a figure of merit for prediction of the on-axis radiation brilliance [6, 7].

The procedure to minimize the phase errors is not unique; there are different ways to achieve a small, about a few degrees, rms phase errors level. The technique selected at the APS uses two types of shims: "pure phase" shims and "pure trajectory" shims. The pure phase shim changes only the phase advance without disturbing the trajectory. The pure trajectory shim changes the phase only in the case in which it changes the trajectory slope toward the direction of observation. A set of such shims with opposite sign of field doesn't change the trajectory in the first approximation and doesn't change the phase. The necessity of making the trajectory reasonably flat in order to achieve a low value of phase errors has been discussed by us and others previously [8, 9].

2. Shimming technique: calculations and experimental results

The problem to be solved in any shimming technique is the proper selection of the shim's dimensions and its position on the magnets of an insertion device. In the case of correction of the trajectory and phase errors for the APS Undulator A, the choice for these variances is quite limited: only the shim's dimension along the particle trajectory (Z) can be varied. All of the other dimensions of the shim are predetermined by the requirement to preserve the different magnetic properties of Undulator A and also by the particular small recess between the poles and the magnet surfaces.

If the shim's length and Z-dimension are equal to the magnet's length and width, only the phase advance would be affected. A shim equal in size to the full top magnet surface will change only the peak field of the poles neighboring the magnet but does not affect the field integrals. This type of shim is considered a pure phase shim. The obvious conclusion from the last statement is: half-width magnet shims are not pure trajectory shims. If the shim's Z-dimension is less than the magnet width, both the phase and the trajectory will be changed in the general case when a shim is placed.

In order to study the magnetic field perturbation at Undulator A as a function of the shim's width, a set of calculations and measurements were conducted. The results of 2-D calculations are presented in Figs. 1 and 2. Figure 1 shows that part of the main magnetic flux through the pole is attracted by the shim placed next to the pole, and, as a result, the peak field of the pole is decreased with a simultaneous increase of the field in the region far from the shim's edge. The shim's "magnetic signature" is presented in Fig. 2. Based on these calculations, a qualitative prediction could be made for the process of shim selection that would correct the trajectory but would not change the phase substantially, i.e., a shim that would compliment the phase shim. The result of this analysis shows that for Undulator A the pure trajectory shim should be about one third of the magnet's width.

The experimental results agree strongly with this conclusion.*

First of all, it has been demonstrated that, if the shim's width is equal to one half of the magnet width, both the phase advance and the trajectory will be affected significantly. The results of the phase perturbation for this case are shown in Figs. 3 and 4. (A set of four shims has been selected in order to eliminate the phase advance due to the trajectory slope change.) One can see from Fig. 4 that the position of the shim's signature maxima and their tails relative to the main field peaks defines the phase change, and the phase advance could be tuned by moving these maxima. If the shim's size in Z-direction would be less than half the width of the magnet, the phase change could be zero. For a shim 4 mm wide, the phase change is less than .5 degree, but the first integral gains compared with the 6-mm shim. Figures 5, 6 and 7 illustrate these results and confirm that this type of shim behaves as a pure trajectory shim.

The practical implementation of the shimming technique based on the use of pure trajectory and phase shims for APS Undulator A brought the rms phase errors to the level of 1-2 degrees. Because of the shim's mutual independence, the time required for the converging of this shimming procedure is quite low.

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*A similar investigation has been conducted recently at ELETTRA [9]. It is worthwhile to point out that practical results depend strongly on the ID magnetic structure.

3. Conclusion

A shimming technique for the minimization of phase errors for the APS IDs has been developed. This technique uses two types of shims: one for trajectory corrections and one for phase corrections. It has been demonstrated that trajectory shims could bring the rms phase errors to the level of 5 degrees, and the next shimming step when only phase shims are applied brings the rms phase errors as low as 1.5 degree.

4. Acknowledgments

The author wishes to thank E. Gluskin for helpful discussions and attention to the work and P. Ivanov for making calculation of shim signature.

5. References

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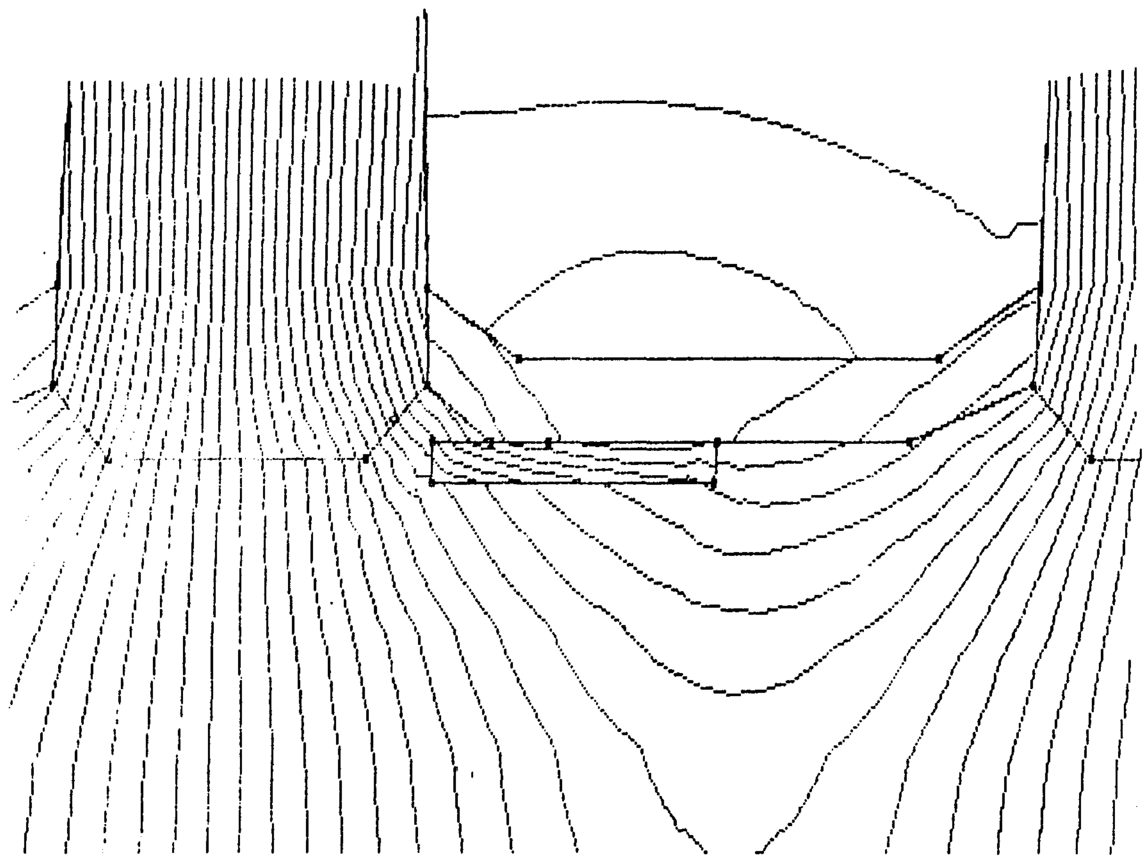
Fig. 1

Field flux 2D calculation using trajectory shims



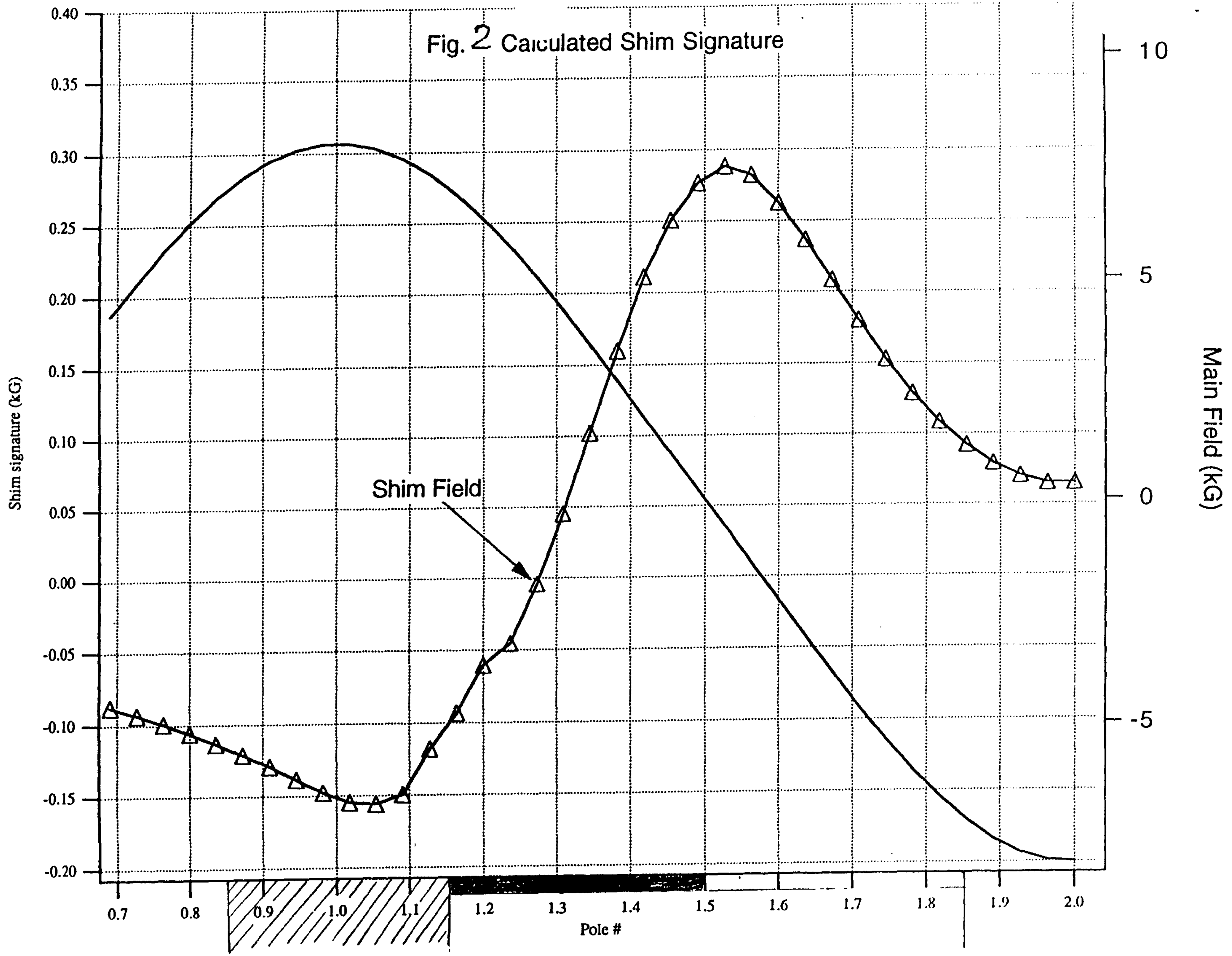


Fig. 2 Calculated Shim Signature
Shim signature (kG)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
-0.15
-0.20
Main Field (kG)
10
5
0
-5
Shim Field
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
Pole #

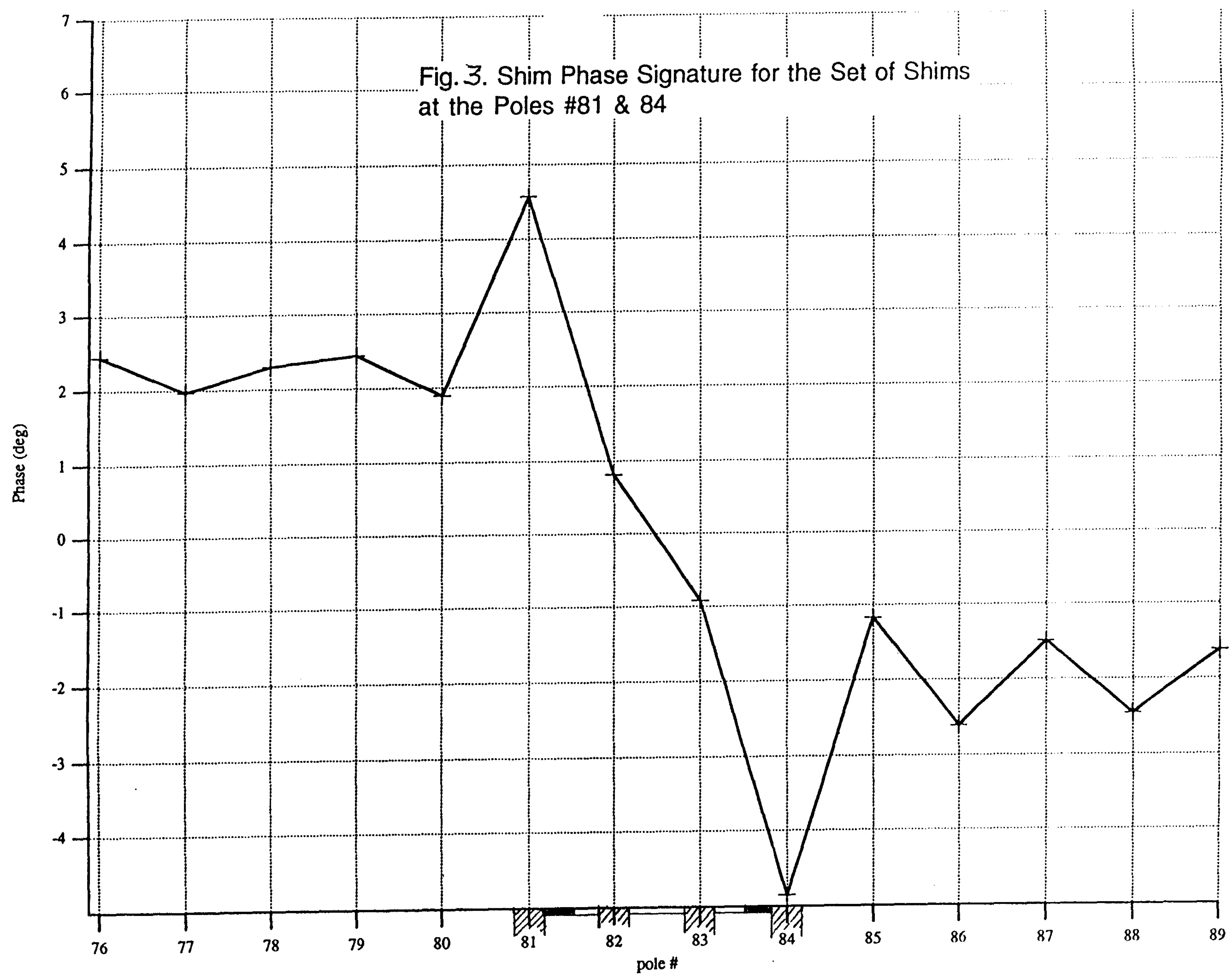


Fig. 3. Shim Phase Signature for the Set of Shims at the Poles #81 & 84
Phase (deg)
7
6
5
4
3
2
1
0
-1
-2
-3
-4
76
77
78
79
80
81
82
83
84
85
86
87
88
89
pole #

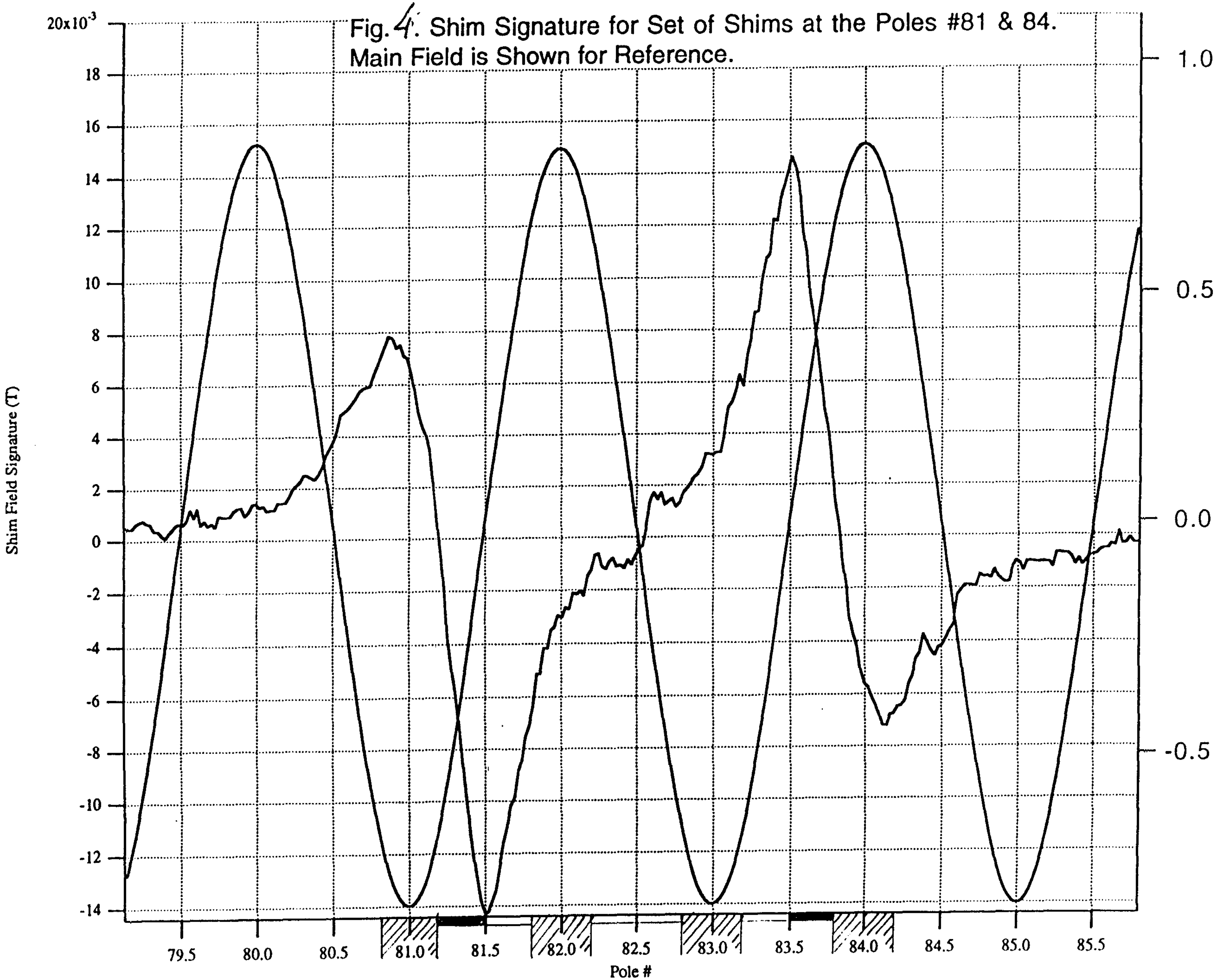
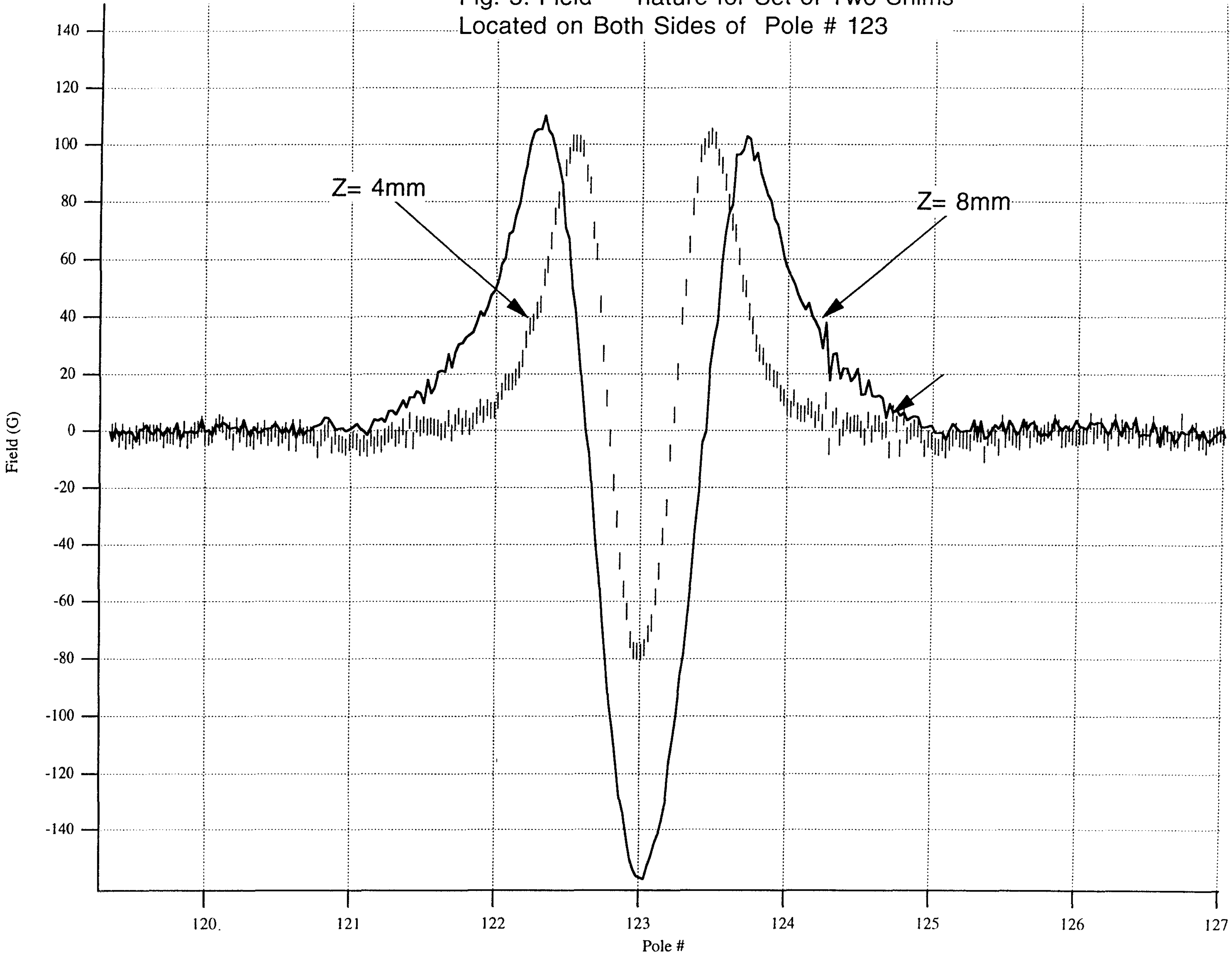


Fig. 4. Shim Signature for Set of Shims at the Poles #81 & 84.
Main Field is Shown for Reference.
20x10-3
18
16
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
-12
-14
Shim Field Signature (T)
1.0
0.5
0.0
-0.5
Field (T)
79.5
80.0
80.5
81.0
81.5
82.0
82.5
83.0
83.5
84.0
84.5
85.0
85.5
Pole #

Fig. 5. Field nature for Set of Two Shims
Located on Both Sides of Pole # 123



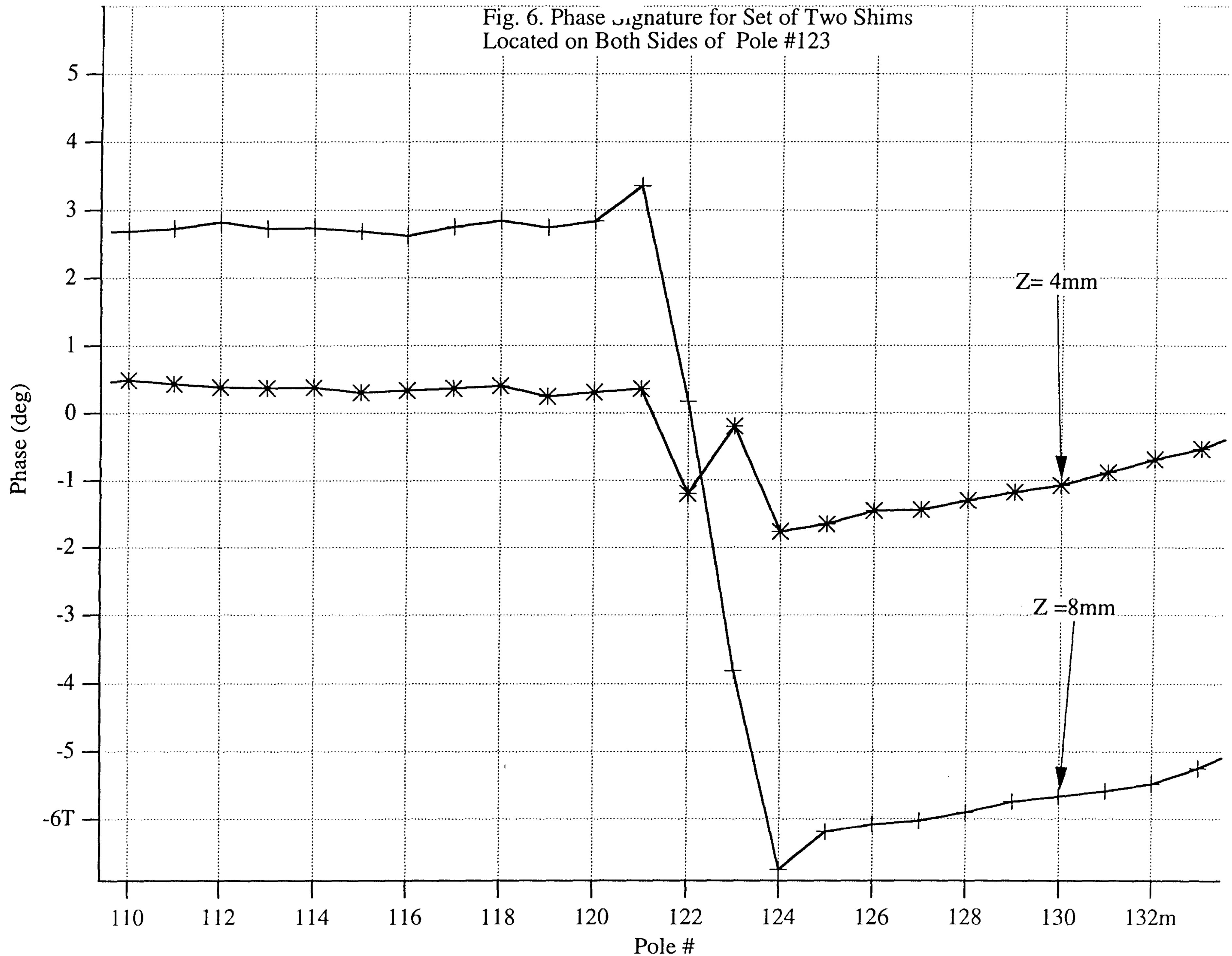


Fig. 6. Phase Signature for Set of Two Shims Located on Both Sides of Pole #123

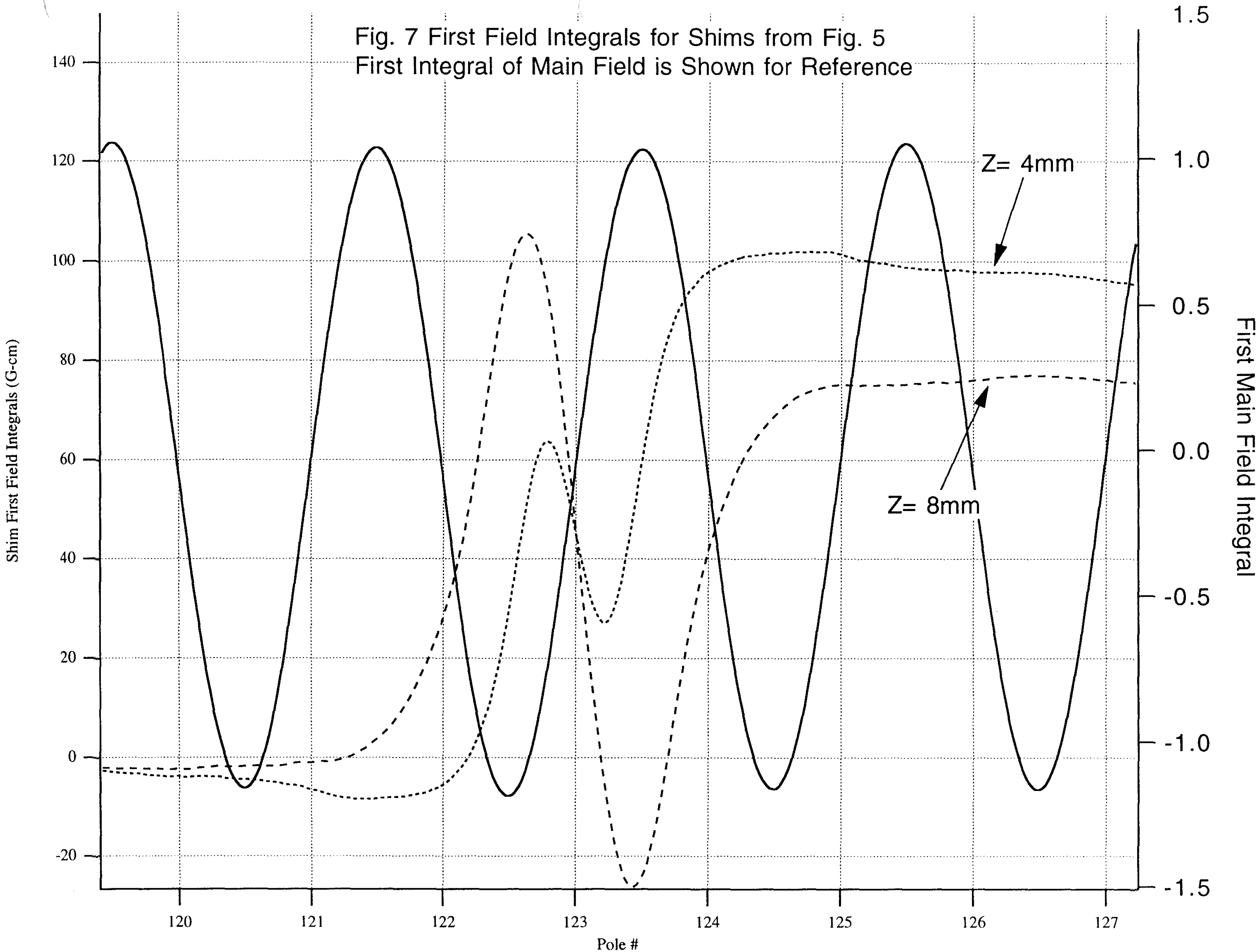


Fig. 7 First Field Integrals for Shims from Fig. 5
First Integral of Main Field is Shown for Reference
Z= 4mm
Z= 8mm
Shim First Field Integrals (G-cm)
First Main Field Integral
Pole #
140
120
100
80
60
40
20
0
-20
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
120
121
122
123
124
125
126
127